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HOT IN-PLACE RECYCLING WITH AND WITHOUT AN INTEGRAL HOT MIX WEARING COURSE PLACED WITH TAISEI ROTEC EQUIPMENT

(CONSTRUCTION REPORT CONT. 87-26)

MATERIALS INFORMATION

ENGINEERING MATERIALS OFFICE

HOT IN-PLACE RECYCLING WITH AND WITHOUT AN INTEGRAL HOT MIX WEARING COURSE PLACED WITH TAISEI ROTEC EQUIPMENT

(CONSTRUCTION REPORT, CONT. 87-26)

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ABSTRACT

In 1987, Warren Bitulithic Limited of Downsview Ontario, in association with Taisei Rotec Inc. of the US, constructed four trial sections of hot in-place recycling on Ontario Ministry of Transportation Contract 87-26.

The equipment was designed to heat, scarify, add rejuvenator, mix and relay an existing asphalt pavement and place a new hot mix overlay in a single pass.

This report covers the construction of the trial sections and presents test data for samples taken during construction. Also presented are results of a roughness survey taken after construction.

BACKGROUND

Warren Bitulithic Limited of Downsview, Ontario was the prime contractor on Ontario Ministry of Transportation Contract 87-26 which called for a combination of cold milling, hot-mix recycling and a new hot mix wearing course. Warren Bitulithic Limited, in association with Taisei Rotec Inc., who developed a hot in-place recycling machine capable of placing an integral overlay, negotiated with the Ministry to incorporate trials of the equipment as part of that contract.

ORIGINAL PAVEMENT CONDITION

Contract 87-26 was divided into two separate portions, one being Highway #24 between Highways #5 and #99, the other, Highway #2 south-westerly from the junction of Highway #5, for 4.2 km.

Highway #24

The Highway #24 portion is a rural four lane highway with an AADT of 7500 (1987). It was constructed in 1956 and later resurfaced in 1970. The pavement structure consisted of an average 207 mm of hot mix over 908 mm of granular material.

The existing pavement was in fair condition with slight wheel track rutting and slight wheel track cracking throughout. There were slight to moderate half and full width transverse cracks throughout which had been spray patched with emulsion and chips.

The contractor's consultant found the average penetration of the asphalt recovered from the top 40 mm of hot mix to be 34.

Highway #2

The Highway #2 portion is on the main route between Paris and Brantford and carries an AADT of 7900 (1987). It was first constructed in 1928 as a 6 m wide concrete pavement and was widened and resurfaced with asphalt pavement in 1950 to 6.7 m. In 1965 it was again resurfaced with a sand asphalt levelling course and a HL-3 surface. The pavement structure was composed of an average 148 mm of hot mix over concrete pavement.

The existing pavement had transverse reflection cracks from the concrete pavement as well as frequent longitudinal cracking between the edge of the concrete and the widening. There was also moderate to severe wheel track rutting and 25 to 30 full width transverse bumps 300 mm wide with severe alligator cracking.

The contractor's consultant found the average penetration of the asphalt recovered from the top 40 mm of hot mix to be 34.

REHABILITATION STRATEGY

Both portions of the contract were designed for a 40 mm depth of cold milling at centre-line maintaining a 2% cross-fall to the shoulders. The resultant reclaimed asphalt pavement (RAP) was to be recycled in a hot mix plant at a ratio of 40% RAP to 60% virgin aggregates.

The Highway #24 portion was designed to have two 40 mm binder courses of recycled hot mix (RHM) and a HL-1 surface course.

The Highway #2 portion was to receive a single 40 mm RHM binder course and a HL-1 surface course.

The design also required the existing pavements to be widened by the addition of a 0.5 m partial paved shoulder on each side.

At the request of the contractor and after negotiations, four hot in-place recycling trials were included in the work.

A 1 km section of the Hwy. #24 portion was dedicated for in-place recycling (IPR) . The treatment was to consist of:

Area #1. N.B. lanes, 12+475 to 13+475
40 mm IPR with an integrally placed 15 mm lift of RHM plus a 40 mm RHM binder course plus a 40 mm HL-1 surface course,

Area #2. S.B. lanes, 12+475 to 13+475
40 mm IPR plus a 40 mm RHM binder course plus a 40 mm HL-1 surface course.

Two 1 km sections of the Highway #2 portion were dedicated for IPR trials. They were to be:

Area #3. Sta. 16+900 to 17+900
40 mm IPR with an integrally placed 15 mm lift of RHM plus a 40 mm HL-1 surface course,

Area #4. Sta. 17+900 to 18+900
40 mm IPR with an integrally placed 25 mm HL-1 surface course.

The IPR was to correct the cross-fall to 2.0% so that the subsequent lifts would be placed at a uniform thickness.

The penetration of the asphalt cement recovered from the IPR was required to be between a minimum of 50 and a maximum of 80.

See key maps, Figures 1 and 2 for locations and details of treatments.

EQUIPMENT

The IPR train consisted of two pre-heaters, the recycling/paver unit, a dual drum vibratory compactor and a 11 t pneumatic tire roller.

The pre-heaters heat the pavement surface with infra-red radiation produced from the combustion of liquid propane gas. The amount of heat applied to the pavement surface is controlled by adjusting the gas pressure to the burners or by adjusting the height of the heating panels from the surface. Both pre-heaters were variable in width from 3.0 m to 4.6 m in 150 mm increments.

The two pre-heaters are intended to heat the top 12 to 25 mm of pavement to 135°C, depending on ambient conditions, which results in a softening of the pavement to a depth of approximately 40 mm.

FIG. 1: KEY MAP, CONT. 87-26, HWY. 24, PORTION

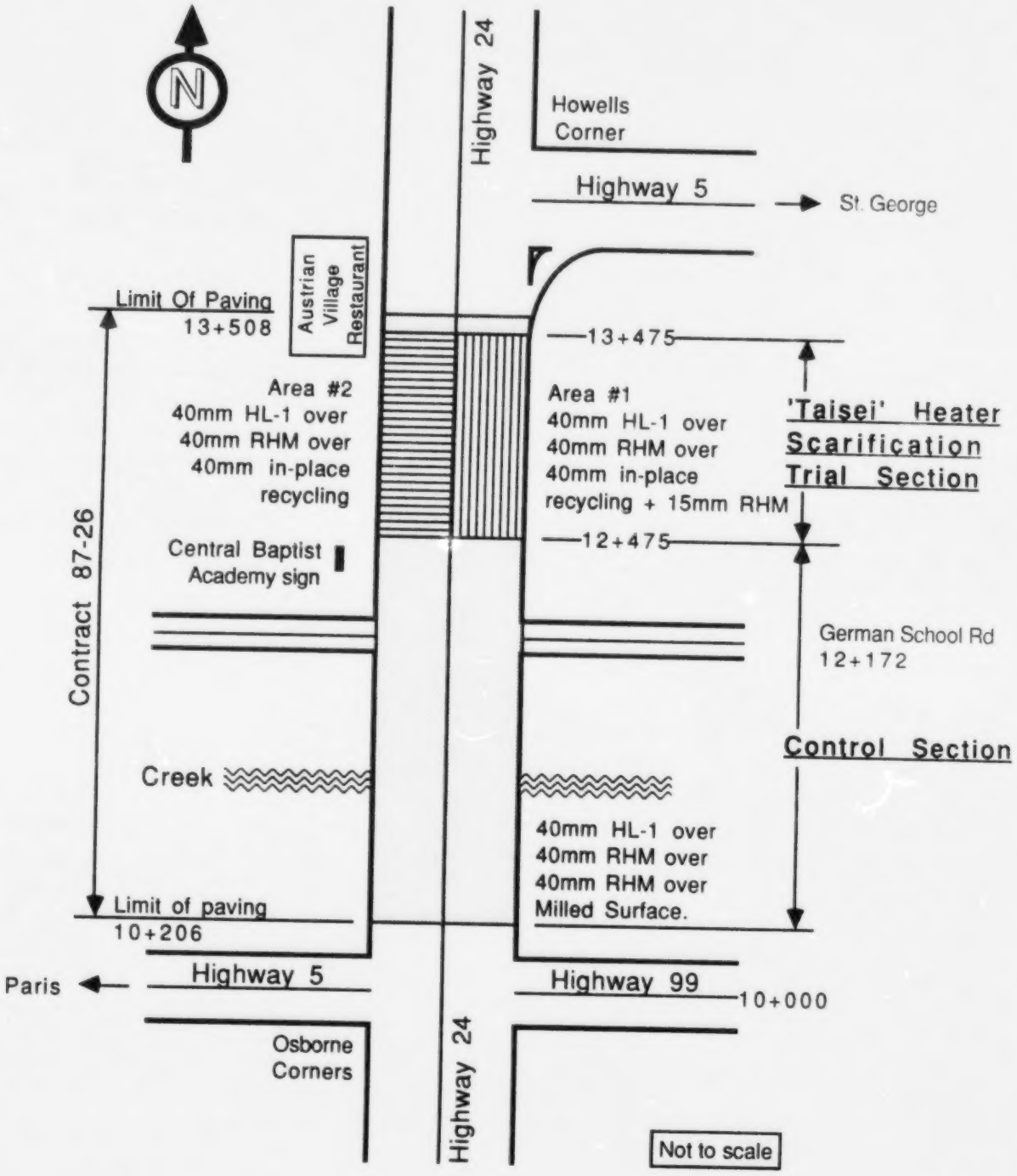
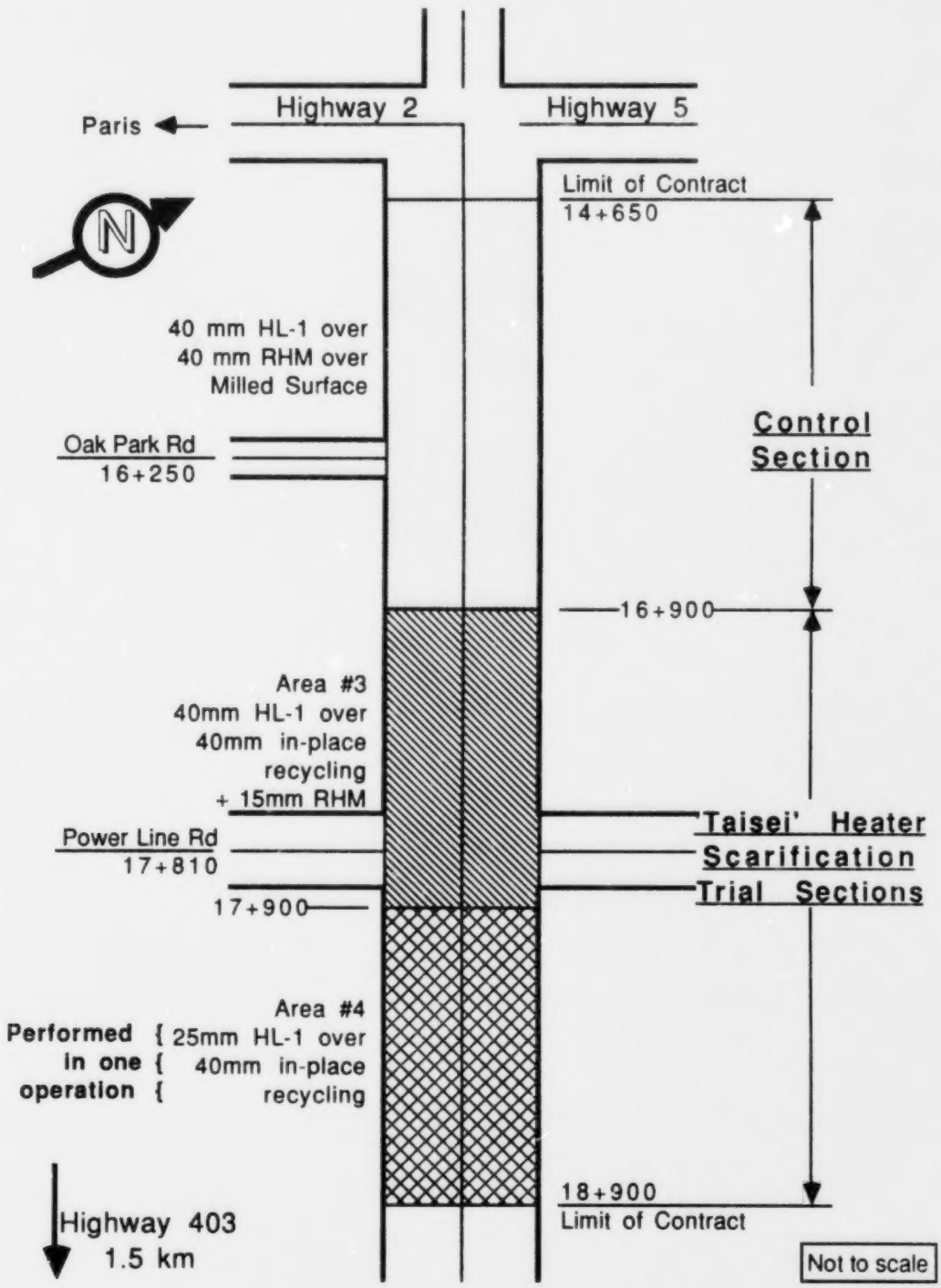


FIG. 2: KEY MAP, CONT. 87-26, HWY. 2, PORTION



The recycling/paver unit consisted of:

- a paver style front hopper for receiving hot mix from a truck,
- an infra-red heater panel,
- retractable fixed cultivator tines to scarify the pavement,
- a spray bar for adding a rejuvenating agent,
- a downward cutting milling arbor used for primary mixing,
- a pair of counter-rotating milling arbors for secondary mixing,
- distribution augers for the recycled mix,
- a primary screed to spread the recycled mix,
- distribution augers for the new mix, and
- a secondary screed to place the new mix.

The machine had the capability of adding new mix to the recycled mix between the primary and secondary mixing arbors. This permitted the inclusion of "make-up" material to compensate for pot-holes, wheel track rutting, etc. when not placing an integral overlay.

The heating panel on the recycling/paver unit was much smaller than those on the pre-heaters and was primarily intended to maintain the heat level rather than raise it.

The working width of the recycling/paver unit was variable from 3.0 m to 4.3 m in 100 mm increments.

CONSTRUCTION

Temperatures

The IPR was constructed in the middle of September 1987. Temperatures were found to vary widely at the various points in the IPR mainly due to, but not restricted to, ambient conditions. At start-up, care had to be taken not to allow the pre-heaters to progress to far ahead of the recycling/paver unit as the pavement would cool too much. In some cases, the second pre-heater was backed up to re-heat the pavement which had cooled too much ahead of the recycling/paver unit.

Monitoring of temperatures twice daily revealed the following:

LOCATION	TEMPERATURE (°C)	
	Average	Range
Behind Pre-heaters	118	110 - 135
Recycled Mix @ Screed	112	100 - 125
Virgin Mix @ Screed	111	90 - 125

In normal operation, an interval of approximately 10 m was maintained between each pre-heater, and the recycling/paver unit.

The pavement was heated on each lane about 150 mm beyond the longitudinal joint so as to allow for scarification to the joint.

The spray patched pavement would frequently catch fire when the pre-heaters or the recycling/paver unit stopped without reducing the heat.

The finished mat was found to retain heat for an inordinate length of time, giving rise to concern that traffic behind the operation might rut the pavement. However, no rutting was noticed.

Rejuvenator

A rejuvenator, Shell RJO-3BR, was distributed onto the scarified pavement inside a shroud containing the first milling/mixing arbor. The addition of the rejuvenator was intended to be controlled by computer but since the micro-processor was defective it was controlled manually by the operator.

The contractor's consultant had estimated that 0.49 L/m^2 of RJO-3BR was required to raise the penetration of the old asphalt cement to a value of 65, the middle of the specified range. Due to the fact that the micro-processor was inoperative and to allow for operator error without overdosing, the application rate was reduced to 0.40 L/m^2. This dosage was expected to yield an average penetration of 56.

The operator controlled the application rate with the aid of a meter and confirmed the quantity used by tank dips. The inspector was unable to tell if the rejuvenator was being applied at any given time because he could see neither the meter nor the point of application.

Scarification / Milling

Prior to IPR the shoulder gravel had to be graded back from the edge of pavement in order to preclude it from inclusion with the hot mix during scarification.

Scarification had to be extended beyond any longitudinal joints to mix in the sand inclusions existing in the cracks. In fact, it was found that sand had migrated between the lifts of pavement as much as 10 mm from the longitudinal cracks.

If the pavement was not heated/softened enough for the scarifying teeth to cut to the desired depth, then the milling arbor could "cold mill" the pavement to the desired depth. In such circumstances, the cold milling had the potential to degrade the coarse aggregate in the mix.

Due to varying cross-fall and wheel track rutting, the depth of scarification varied.

The actual depth of scarification/milling was virtually impossible for the inspector to determine.

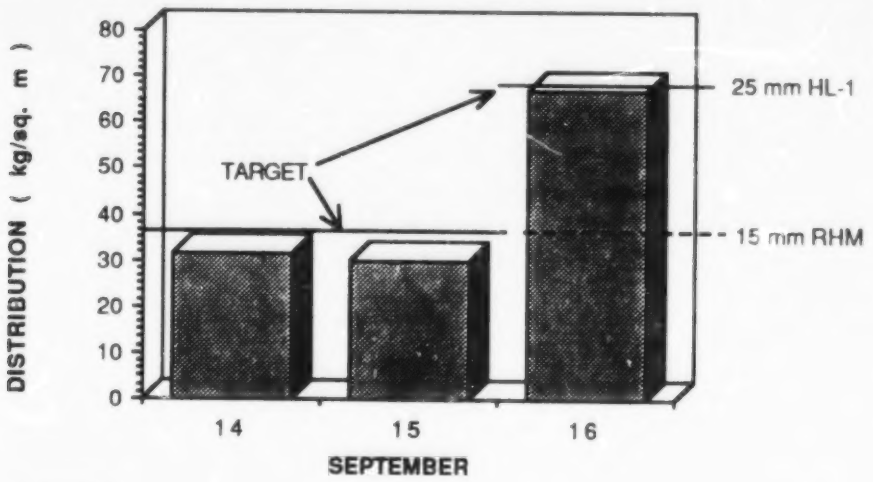
Distribution

At start-up, even when an integral overlay was not being placed, three to four tonnes of new mix was required to make the starting joint. In section 2 (no integral overlay) 50 t of new mix was used as make up material in the IPR operation. This is equivalent to 7.3 kg/m^2 or a depth of approximately 3 mm overall.
When an integral overlay was being placed the only way to determine the actual depth placed was to compare the actual number of kilograms used to cover a given area to the theoretical quantity required. This was done on a truck-load basis. Figure 3 depicts the actual quantities used against the target quantity.

New mix being added ahead of the second screed would hang-up behind the auger on a steel plate ahead of the screed, cool and then drop off intermittently and cause tearing of the mat as the material passed under the screed. This hung-up, cooled material also contributed to difficulty in making the transverse end joints.

The recycling/paver unit was not equipped with automatic grade and slope controls necessitating frequent manual checking of cross-fall.

FIG. 3: DISTRIBUTION OF MIX IN INTEGRAL OVERLAYS



Compaction

The dual drum vibratory breakdown roller worked to within 1 m of the screed and rolled the mat from shoulder to crown. The pneumatic tire intermediate/finish roller followed at approximately 30 m and also worked from shoulder to crown.

Finished Work

Where no integral overlay was placed the IPR mat was quite variable in texture with areas of flushing throughout. This was attributed to the extra asphalt cement in the spray patched areas and to the spilling of new mix onto the pavement ahead of the recycling/paver unit when the trucks delivering hot-mix dumped into the paver hopper. This spillage could be minimized if the machine were to be equipped with wheel harnesses to prevent the trucks from separating from the machine and with proper flexible containment baffles. Regardless of the source of extra asphalt cement, the fact that the mat was variable indicates that there was insufficient mixing of the materials in the IPR.

When an integral overlay was placed the resultant mat had a coarse open texture which was attributed to an improperly adjusted screed.

Transverse start-up joints were satisfactory but the transverse end joints were very coarse textured and bumpy due to hand work and the cooled material built up ahead of the second screed.

The longitudinal joints were straight and satisfactory.

Productivity

The IPR advanced at an average rate of 4 to 5 m/min. The average daily production was 2 km of single lane construction.

Traffic Control

Traffic control was maintained by two flag persons equipped with two-way radios.

On Highway #24, there were no problems maintaining two-way traffic due to the four lane configuration. On Highway #2, one-way traffic was controlled over approximately 500 m with some inconvenience to the motoring public.

ENVIRONMENTAL ASPECTS

Smoke emissions from the operation were heavy, principally due to the spray patches on the existing pavement surface. The smoke could be reduced by lowering the heat to an unacceptable level which precluded scarification to designed depth.

The heavy smoke could be tolerated in this rural environment but would not be acceptable in an urban situation.

SAMPLING

The contractor was required to obtain samples of the recycled mix plus a 4 L sample of rejuvenating agent. The contractor's consultant obtained the samples, retained some for testing and turned over the balance to the Ministry for testing. The samples of recycled mix were obtained from the auger just ahead of the primary screed.

TESTING

Fourteen samples of in-place recycled mix from throughout the project were tested in the Ministry's Downsview laboratory for:

1. asphalt cement content,
2. penetration of the recovered asphalt,
3. gradation of the extracted aggregates and
4. Marshall values.

Table 1 summarizes the test values obtained.

TABLE 1: IN-PLACE RECYCLED MIX, TEST DATA

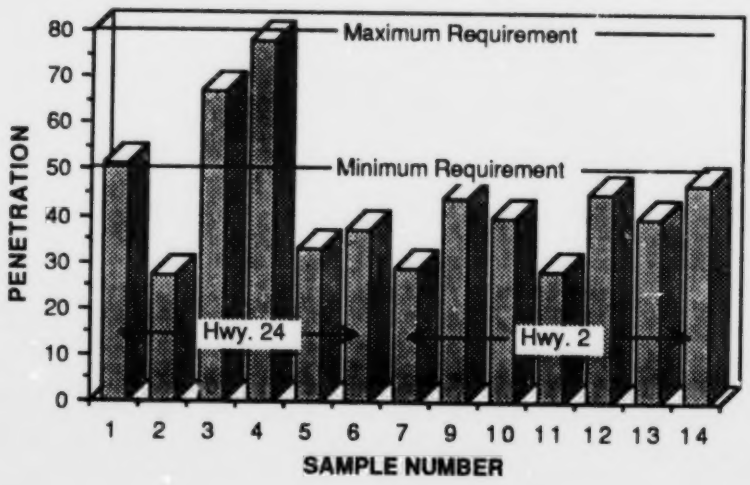
SAMP. /HWY.	A.C.	PEN.	+ 4.75 mm	+ 75 µm	VOIDS	FLOW	STAB.
1/24	5.79	51	44.3	92.5	0.0	24.5	10263
2/24	6.07	27	27.2	91.0	2.0	18.4	16809
3/24	4.97	67	48.8	97.2	3.5	8.7	12975
4/24	4.74	78	51.9	97.5	1.9	9.7	11334
5/24	5.45	33	33.0	92.3	1.6	18.2	17861
6/24	6.45	37	19.6	89.7	1.7	18.9	12416
7/2	4.73	29	50.5	95.0	2.6	14.9	16600
8/2	5.65	*	41.8	93.3	1.9	15.3	11342
9/2	5.14	44	45.5	93.9	1.9	12.5	12416
10/2	6.39	40	24.9	95.0	3.7	12.4	14471
11/2	4.91	28	43.3	94.8	4.0	12.2	18980
12/2	5.17	45	51.3	96.5	1.8	10.6	14273
13/2	5.28	40	33.4	95.5	2.5	12.6	14341
14/2	4.62	47	60.9	97.0	3.4	10.8	15127
Mean	5.38	43.5	41.2	94.4	2.32	14.3	14229
St. Dev.	0.61	15.0	11.9	2.38	1.06	4.40	2624

* Insufficient material for test.

The variability of asphalt cement and + 4.75 mm content is higher than would normally be expected with a virgin mix. The high variability is no doubt the result of the inclusion of patching materials and the underlying HL-2 leveling mix.

The mean penetration value of 43.5 is estimated to be equivalent to a 5 to 10 year old pavement. Only 23% of the samples met the requirement for penetration of the recovered asphalt. See Figure 4 for a visual presentation of the penetration values. The range of penetration results from a low of 27, (the original condition) to 78 is unacceptable. If it is assumed the four low values (samples 2, 5, 7, & 11) represent areas not receiving any rejuvenator and these values are discarded, then the average penetration is 49.9. The contractor's consultant, after discarding a low value where no rejuvenator was added, found the average penetration to be 53.7. This is not a significant difference from the Ministry's determination.

FIG. 4: Penetration Values Of Recovered Asphalt



Only four of the fourteen samples met the Ministry requirement of 3 to 5% voids for a binder course pavement.

All samples had flow values above the minimum requirement of 8. Samples 3 and 4 had the lowest flow values and the two highest penetration values. However, the relationship seems to end there. An examination of the coefficient of determination for flow vs penetration yields only an r^2 of 0.16.

All the stability determinations are within acceptable limits but are higher than actual due to the reheating of the mix in the laboratory.

The Ministry normally obtains samples of hot mix by paving over a steel plate template and then lifting it out of the mat as a full depth sample. This method yields a representative sample of what was placed on the road. Unfortunately this is precluded with IPR due to the nature of the operation and the samples had to be obtained from the screed augers.

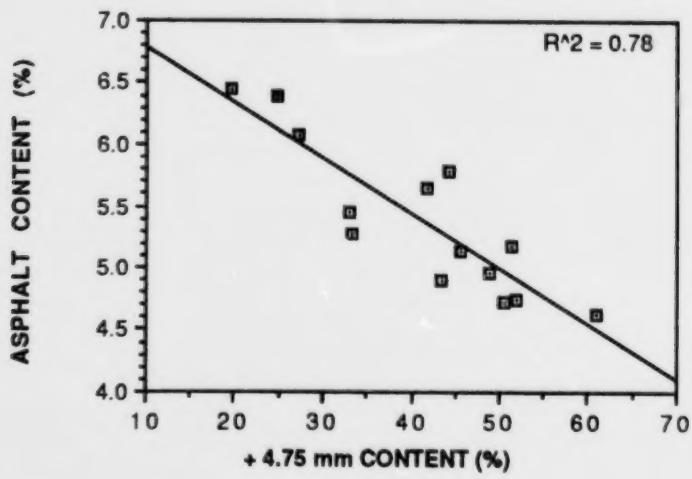
Since samples obtained from the augers have the potential to be segregated, test results of asphalt cement content or gradation of the extracted aggregates are suspect. In fact, the test data supports this assertion, for when the asphalt cement content determinations are plotted against the + 4.75 mm determinations (Figure 4) a strong relationship exists with a coefficient of determination (r^2) of 0.78.

The fact that the + 4.75 mm content varies greatly and the asphalt cement content varies proportionately is indicative of segregation.

Asphalt content determinations can also vary due to insufficient mixing as evident in the mat where no integral overlay was placed.

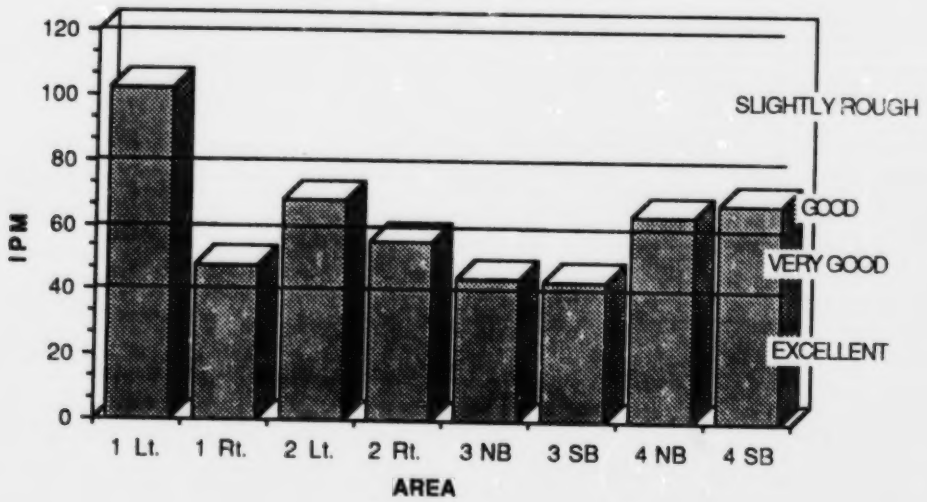
Test results on the penetration of the recovered asphalt should be considered valid, since segregation of the mix has no influence on these results.

FIG. 4: ASPHALT CEMENT vs + 4.75 mm CONTENT



Roughness measurements were taken after construction with a Mays Ride Meter which records roughness in inches per mile (IPM). The results of the roughness survey are presented in Figure 5.

FIG. 5: MAYS METER ROUGHNESS SURVEY



DISCUSSION

The demonstrated advantages of in-place recycling with Taisei Rotec equipment over cold milling and recycling through a hot mix plant, are:

1. no cold milied surface to maintain traffic on,
2. no stepped longitudinal or transverse joints,
3. positive control over the depth of treatment,
4. little or no degradation of aggregates in the mix,
5. low operational noise level,
6. little or no debris to remove and
7. only a one-time disruption to traffic.

The disadvantages were:

1. the penetration of the asphalt cement in the recycled mix was unacceptably variable and low,
2. the addition of recycling agent was variable and often inappropriate,
3. there was no means for an inspector on the ground to monitor the application of rejuvenator,
4. the IPR mix was not uniformly mixed,
5. heat waves and smoke restricted motorists' visibility,

6. difficult to determine actual depth of scarification,
7. the recycling/paver unit was not equipped with a device to couple it to the trucks dumping new mix into the front hopper,
8. the front hopper did not have adequate flexible containment baffles to prevent spillage of new mix in front of the machine,
9. the recycling/paver unit was not equipped with automatic grade and slope controls,

The performance of the trial will be monitored on an ongoing basis.

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